DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

REPORT OF TEST BY THE DIRECTOR OF FUEL RESEARCH ON PARKER LOW TEMPERATURE CARBONISATION PLANT INSTALLED AT BARUGH, BARNSLEY, AT THE WORKS OF LOW TEMPERATURE CARBONISATION, LTD.

Test carried out July 22nd to 24th, 1924

PRICE 9d. NET

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PREFATORY NOTE

THE Department of Scientific and Industrial Research has been empowered by the Government to make tests at the public expense of plants for the low temperature carbonisation of bituminous coal. A copy of the published conditions for such tests is reproduced as an appendix.

The object of these tests is to place, in the hands of those interested, accurate technical data on the quality and quantity of yields, the throughput of the plant, the working temperatures, and the general ease of working, together with such other information as it may be possible to obtain under the limited conditions of the tests. It should be clearly understood that no attempt is made to pronounce on the commercial possibilities of plants which may be tested. The likelihood of commercial success can only finally be judged after working a plant under a steady load for a long period, and in the light of complete knowledge of local conditions such as cost of raw material, quantity of raw material available, price and markets for products, cost of labour, etc.

The present Report describes a test of a "standard unit" of "Parker" plant for the low temperature carbonisation of coal installed at Barugh, Barnsley, at the works of Low Temperature Carbonisation, Ltd.

The conclusions which may be drawn from the Report are as follows:—

1. The throughput of the plant with all retorts working would be 50 tons per day (32 retorts), and would be in accordance with that claimed.
2. The products obtained were satisfactory both in quantity and quality. The yields were on the average slightly better than those which have been obtained with similar coal on an intermediate scale at H.M. Fuel Research Station.
3. Certain defects in the plant showed themselves during the course of the trial, but it is considered that there should be no difficulty in overcoming these defects in future designs.

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CONTENTS

LOW TEMPERATURE CARBONISATION

TEST ON PARKER PLANT INSTALLED AT BARUGH, BARNSLEY, WORKS OF LOW TEMPERATURE CARBONISATION, LTD.

Carried out July 22nd to 24th, 1924

INTRODUCTION

DURING July, 1924, it was arranged that an installation of "Parker" retorts for the manufacture of smokeless fuel by the carbonisation of coal at low temperature should be tested officially by the staff of H.M. Fuel Research Station.

A preliminary inspection of the plant was made on July 14th by Engineer Captain Shaw and Mr. King, respectively Chief Engineer and Chief Chemist of the Fuel Research Station, in order to determine what apparatus would be necessary and also what arrangements would have to be made in the operation of the plant in order to carry out a satisfactory test.

The installation consisted of two settings of 32 retorts each, each setting being designed to carbonise 50 tons of coal per 24 hours. One setting was in operation while the other was being heated up in preparation for the proposed test.

It was decided that the test should, if possible, commence on July 21st, by which time the second setting of retorts would have been in operation for over a week and steady working conditions should have been attained.

The test was witnessed by Mr. P. C. Pope, Engineer and Manager to Low Temperature Carbonisation, Ltd., and by the Works Manager, Mr. A. A. Girling, who supervised the running of the plant. The operations on the retort bench were supervised by Mr. Parker, Junr.

DESCRIPTION OF PLANT

The general lay-out of the plant is shown diagrammatically in the drawing (Fig. 1). The pipe lines and recovery plant had not been specially constructed to suit the setting under examination, but had been altered and adapted from the services of a former plant. The setting not in use during the test is shown dotted.

Each setting consists of a battery of 32 retorts, arranged as shown, the offtake pipe of each leading to a hydraulic main running along the side of the setting.

A retort consists essentially of an iron casting in one piece containing 12 vertical tubes arranged as shown in the drawing. These tubes taper from 4½ inches diameter at the top to 5½ inches diameter at the bottom, and are 9 feet in length A special

iron swing door, operated by a wheel on the charging platform, closes the bottom of the retort tubes and separates them from a cooling chamber. This chamber is built of brick and one chamber is provided for each pair of retorts. A gas-tight door allows access to this chamber for discharging coke. When the coke is cooling in the chamber any gas liberated is drawn off into a secondary main below the hydraulic main. The gas leaving the system passes through a governor to a condenser (air-cooled), an exhauster, a tar extractor, an oil-washing plant, a rotary gas-meter and finally to a holder (of 25,000 cu. ft. capacity). In this holder it is mixed with producer gas and the mixture used as a fuel gas to heat the settings. Two main seals are provided, one at the end of each hydraulic main, and from these the tar and liquor flow to a collecting tank. The tar and liquor from the condenser and from the seals below the exhauster and tar extractor flow to a different collecting tank.

OPERATION OF PLANT

The retorts are operated in pairs in the following sequence :—

(1) The coke cooling chamber is emptied of coke, which has been cooling since the last discharge 4 to 5 hours previously, and spread out to cool further.

(2) The gas valve of one retort is closed, the bottom door opened and the cover removed. Any coke which does not fall into the cooling chamber is poked down by an iron rod.

(3) The second retort is similarly discharged.

(4) The bottom doors are closed and the retorts charged simultaneously by the feed hopper.

(5) The top of the charge is trimmed off with a spade, the outlet pipe cleaned, the cover closed and the gas valves to the hydraulic main opened.

This sequence of operations takes from five to ten minutes, depending on the ease with which the coke is removed from the retorts. With a four hours' charging period four pairs of retorts are due for discharge each hour, allowing a maximum time for each pair of fifteen minutes.

The cover of the retorts is fitted with a one-inch plug, which is left out during the period between the closing of the retorts and the opening of the gas valves.

The coke discharged is left to cool in the chamber until just before the next charge is due, four hours later. Cooling is accelerated by running a small stream of water continuously into the chamber. A few minutes after discharge the coke is lifted by forks into an iron skip and removed. The breeze remaining on the ground is lifted at longer intervals.

The control arrangements consist only in maintaining a pressure of $-\frac{1}{10}$ to $-\frac{3}{10}$ inch on the hydraulic main and of maintaining the carbonising temperatures at from 620° to 660° C.

A small stream of water is run into each hydraulic main to help to keep these cool during working. This amount is however not sufficient for continuous working and the main is flushed out once per shift to remove heavy tar and any coal dust which is carried over. With this precaution no trouble was experienced with chokage of the collecting system.

ARRANGEMENTS FOR TEST

The coal provided for the test was Dalton Main, Rotherham, a coal with which the Fuel Research Station have already had considerable experience. The setting had been in continuous operation on this coal for some eight days.

In order to start the test the main bunker was emptied and filled up again with a weighed quantity of coal. The retorts were then worked steadily until the coal in the second bunker supplying the setting was empty. The time of the first charge of weighed coal was regarded as the starting point of the test.

The other conditions at the start were as follows :—

(1) The tar collecting tanks were at their lowest possible level and all the seals were full.

(2) The water supply to the hydraulic main was fixed at a constant rate.

(3) The reading of the make meter was taken immediately.

It was assumed that the maintenance of steady conditions for a period of several days before the start of the test would result in a general working state, which would not be materially different from that at the end of the test. Such an assumption is always necessary in a continuously operated plant and in this instance was, as far as could be judged, entirely justified. The total volume of tar and liquor in the seals was not a large proportion of the amount collected daily so that any small changes in composition would have a negligible effect.

Unfortunately this test had lasted for only a few hours before a breakdown of the exhauster necessitated a fresh start. The working conditions on the retorts were not steadied down until about 2 hours later and it was decided that at least 12 hours should elapse before a second start was made.

Special arrangements (see page 5) were therefore made with regard to the coal measurements and a fresh start was made under the same conditions as before.

CONDITIONS OF TEST

The first attempt at test conditions was made at 12.38 p.m. on Tuesday, July 22nd, and the exhauster breakdown took place about 5 p.m. At 1.55 p.m. the bottom door of one of the retorts sheared off and this retort and its neighbour had to be closed off.

On Wednesday morning the second start was made at 7.40 a.m., by which time the setting had been under observation by the Research Station staff for 48 hours.

This time no difficulties occurred and the staff was divided up to keep the work under continuous observation (24 hours per day).

Routine observations were taken in accordance with the following instructions :—

	Period.
(1) Meter readings—two (make and fuel gas) ...	2 hours.
(2) Tar tanks—three (Nos. 1, 2 and 3)	2 ,,
(3) Water to main—two (right and left)	2 ,,

(4) Benzol washing.—Measure each drum, draw 200 cc. sample and discard. Each drum will be filled in 3-4 hours. 1 inch on drum = 0·55 gallons. When sampling spirit take 200 cc. wash oil and 200 cc. of the oil containing spirit. Record temperature of scrubber.

(5) *Gas samples.*—$\frac{1}{2}$ inch on tube every hour. Mark tube to show time of start and finish.

(6) *Coke.*—Occasional observations on man doing sampling. Weigh trucks as filled.

(7) *Breeze* (less than $\frac{1}{2}$ inch).—Weigh and sample wagon when full.

(8) *Gas calorific values and specific gravities.*—Recorder on scrubbed gas to be checked as often as possible—at least twice per 8 hours. Water supply tank must be watched. Calorific value of unscrubbed gas to be taken at intervals between observations on scrubbed gas. Specific gravities to be determined periodically.

(9) Time of charging and discharging of retorts to be noted down from the checker's book.

Special observation and samples were taken as follows :—

(1) Weight of coal used during test.
(2) Weight of coal carried over by elevator.
(3) Temperatures on setting.
(4) Take samples of unscrubbed gas.
(5) Wash unscrubbed gas with benzol in laboratory.
(6) Sample producer gas.
(7) Labour, etc.
(8) Working conditions on plant.

The routine observations were continued throughout the whole period of the test and the special observations as opportunity occurred.

The test proceeded without special difficulty and was concluded when the weighed quantity of coal was consumed and the first retort charge of fresh coal was due. Owing to shortage of coal only 92 tons were available and the test was brought to a conclusion at 6.40 a.m. on Friday, July 25th.

At this moment the final gas readings were taken, the tar collecting tanks measured and sampled and the coke removed quickly before the next discharge was due.

All samples were sealed up and despatched to the Fuel Research Station, Greenwich, and in addition 2 cwts. of coalite were sent by goods train as a test of friability (see page 8) and for use in connexion with combustion tests (see page 9).

COAL USED

The coal used was Dalton Main, a medium caking coal, in the form of washed breeze up to $\frac{1}{2}$ inch pieces. The coal was clean and of uniform quality.

The first test was started with the large hopper (of 50 tons capacity) empty, but when the second test was due to start this hopper still contained some 40 tons and the working out of this would have caused an unnecessary delay. The coal was therefore carefully levelled off in the hopper, which was rectangular in shape, and measurements taken from the top edge. When this coal was used up a weighed quantity was again put into the bunker to bring it back to approximately the same level and measurements were again taken. The bulk density of the coal was determined and used in calculating the correction due to the difference in level and thus the weight of the original contents of the bunker was obtained.

Two determinations of the bulk density of the coal were carried out by levelling and measuring a weighed truck of coal. The results obtained were as follows :—

		(1)	(2)
Coal in cu. ft. per ton	=	45·40	45·45
,, in lbs. per cu. ft.	=	49·34	49·28

As one inch on the bunker represented 10·36 cu. ft. or 511 lbs. of coal it was estimated that the accuracy of this measurement of coal consumed was within 150 lbs. or 0·2 per cent. of the total coal consumed.

During the elevation of the coal to the large bunker an average sample was taken by removing a uniform quantity at regular intervals from the elevator buckets. Two samples were taken to represent approximately the first and second halves of the test and these were reduced to laboratory size immediately. Auxiliary samples were also taken and sealed at once, in order that the moisture as charged could be determined.

From the large storage hopper the coal was conveyed to a feed hopper above the retorts by means of a scraper conveyor. This conveyor carried a proportion of the coal over the top into an end bunker. Towards the end of the test this quantity was collected and returned to the feed hopper.

Altogether 91·66 tons of coal were consumed during the test and the first and second samples represented the first 34 and the remaining 58 tons respectively.

The analysis of these samples are given below :—

Proximate analysis (air-dry) :—

	First 34 tons. per cent.	Remaining 58 tons. per cent.
Moisture	2·70	2·30
Volatile matter, less moisture ...	36·20	35·42
" Fixed carbon "	56·10	57·84
Ash	5·00	4·44
	100·00	100·00
Moisture as charged	4·30	5·72

The ultimate analysis of the dry average sample was carbon 80·05 per cent., hydrogen 4·95 per cent., sulphur (combustible) 1·10 per cent., nitrogen 1·60 per cent., oxygen 7·40 per cent., ash 4·75 per cent.

To make certain that there was no variation in the quality of the coal throughout the test the assay of the two samples was also carried out on the dry coal.

Laboratory Assay at 600° *C.*

——	Sample 1	Sample 2	Mean yield as per ton of coal
	Per cent.	Per cent.	
Coke*	74·60	74·11	14·85 cwts.
Gas	8·32	8·46	4,105 cu. ft.
Tar†	12·32	12·54	27·91 galls.
Liquor	4·49	4·50	10·07 galls.
NH_3	0·10	0·10	S/A 8·7 lbs.
	99·83	99·71	

The temperatures of apparent decomposition in the assay apparatus were as follows :—Water appeared at 310° C., fumes at 330° C. and oil at 380° C.

The coke was fairly dark with silvery lustre ; hard and compact on outer layers, but slightly swollen and cellular in the centre.

The above figures show that the coal supply was very uniform throughout the period of the test. The results are also fairly similar to those of the Dalton Main samples already examined

* Wherever the term " coke " is used in this Report it refers to the product which has been given the trade name of " Coalite " by Low Temperature Carbonisation, Ltd.

† Wherever the term " tar " is used in this Report it refers to the crude oils produced by the low temperature carbonisation of coal.

at the Fuel Research Station. The assay results indicate that the coal was somewhat more strongly caking than usual, as normally the coke formed is hard and dense with an entire absence of large cells. This is also borne out in the caking index (Campredon-Gray test), which is 19 as against an average of 15 to 16 in former Research Station samples.

WEIGHT AND THERMAL BALANCE

In experimental work at the Research Station the weight balance of a carbonising test is regarded as the criterion of the reliability of the test as a whole. A weight balance was therefore prepared of the Barnsley test and gave the following results :—

	Tons.
Coal charged at 5·2 per cent. moisture ...	91·66
Water to hydraulic main	1·81
	93·47
Coke discharged (dry)	63·81
Tar collected (dry)	8·10
Liquor collected	10·73
Spirit collected (dry)	0·60
Gas collected (saturated)	9·78
	93·02

The difference, or loss, amounts to 0·45 of a ton or 0·48 per cent. of the materials added to the system and may be regarded as very satisfactory.

A thermal balance of the products was also worked out as a further check on the accuracy of the test :—

	Per cent.
Coal charged, at 13,640 B.Th.U's per lb....	100·0
Coke discharged, at 13,720 B.Th.U's per lb.	70·1
Gas, scrubbed, at 705 B.Th.U's per cu. ft....	13·0
Tar, at 16,540 B.Th.U's per lb.	10·7
Spirit, at 20,000 B.Th.U's per lb. (approx.)	1·0
	94·8

This difference of 5·2 per cent. of the heat units in the coal added may be regarded as quite satisfactory.

From these data it may be assumed that the test was a satisfactory one and that the assumption of parallel conditions at the beginning and end of the test was justified.

The complete examination of the products of carbonisation was carried out at the Research Station and the details of this examination together with relevant data regarding their production is given below under separate headings.

COKE OR "COALITE"

The coke, or coalite, as discharged was chiefly in the form of lumps varying in size from 2 to 3-inch cubes. The diameter of the retort-tubes is approximately 5 inches and the cylinders of coke appeared to break up naturally into triangular pieces about 3 inches long, each representing roughly one-quarter of the cross section of the tube. Continued observance of the coke discharge showed that this phenomenon was quite constant and that only a relatively small number of larger pieces were formed.

From this particular coal the coke was dark grey with a slight silvery lustre. In texture it was hard and compact except in the centre of the retort, where there was a cellular core of about 1-inch diameter. The presence of this cellular core would seem to indicate that the admixture of a small percentage of non-caking coal would have been advantageous. The amount of breeze (passing a $\frac{1}{2}$-inch sieve) was small, amounting to 4·67 per cent. of the coke discharged.

Two bags, each containing 1 cwt. of coke were despatched by goods train from Barnsley and after an eight days' journey the coke was sieved at the Fuel Research Station.

——	1st bag	2nd bag	Mean
	Per cent.	Per cent.	Per cent.
Left on 2-inch sieve ..	54·1	56·6	55·4
Through 2-inch, on 1-inch ..	41·4	38·1	39·8
Through 1-inch, on $\frac{1}{2}$-inch ..	1·8	1·8	1·8
Through $\frac{1}{2}$-inch, on $\frac{1}{4}$-inch ..	1·1	1·0	1·0
Through $\frac{1}{4}$-inch	1·6	2·5	2·0

The low percentage of dust may be taken as an indication that the coke is not friable and will stand ordinary transport. The uniformity of size is noteworthy as indicated by the fact that 40 per cent. of the total is represented by 1 to 2-inch pieces.

During the period of the test several coke samples were taken to determine whether there was any variation in the quality of the average coke produced. From observations of the carbonising temperatures it was apparent that the retort charges were not all being carbonised to the same extent. The average cokes over approximately twelve-hour periods showed, however, very little variation in composition.

Sample	1	2	3	4	Average sample
	Per cent.				
Proximate analysis (air-dry)—					
Moisture	3·25	3·37	2·66	3·27	3·40
Volatile matter, less moisture	3·51	4·63	4·17	3·91	4·20
"Fixed carbon"	86·39	85·59	86·79	86·32	86·00
Ash	6·85	6·41	6·38	6·50	6·40
			100·00		

The volatile matter was determined by heating the coke to 925° C. in a current of nitrogen and is therefore lower than the empirical figure generally quoted and obtained by ignition in a platinum crucible. In the case of the average sample this figure was determined and found to be 6·24 per cent. or 6·46 per cent. on the dry coke. Even this value is somewhat low and, as stated below, has the effect of reducing the amount of flame obtained when burning the coke in a domestic grate.

In the breeze sample the ash content was appreciably higher, owing probably to the manner in which it was gathered up from the ground round the setting.

Proximate analysis of breeze

	Per cent.
Moisture, as weighed	10·37
Moisture (air-dry)	4·15
Volatile matter, less moisture	6·23
" Fixed carbon "	78·37
Ash	11·25
	100·00

The calorific value of the air-dry coke was 13,250 B.Th.U's per lb. or 13,720 B.Th.U's on dry coke. The ultimate analysis of the average sample calculated to dry coke was 86·02 per cent. carbon, 1·98 per cent. hydrogen, 0·94 per cent. sulphur, 1·78 per cent. nitrogen, 6·62 per cent. ash and 2·66 per cent. oxygen by difference.

A fire was lighted with paper and wood in the normal manner and kept going for about eight hours. The coke ignited readily and gave a good glowing fire. The flame produced was very slight, but otherwise the appearance of the fire and the rate of combustion were very satisfactory.

GAS

The gas leaving the retorts passed through the air-cooled condenser, the exhauster and the tar-extractor. It was then washed with creosote oil in two large towers to remove condensible light spirit, metered and passed to a gas holder.

Two sample pipes were led into the laboratory, one from each side of the gas washing plant, to provide gas for testing purposes. The purified gas was supplied to a Simmance Calorgraph to record continuously the changes of calorific value.

A Simmance calorimeter was also available for checking the readings and for snap readings of the unwashed gas.

It was found almost at once that the calorific value of the gas was subject to wide variations. At first the gas-washing plant was suspected, but later when it became evident that the gas volumes were also showing wide variations the plant was inspected for leakage. It was found that the pull of the exhausters on the retorts was generally too great, viz., 0·35 inches of water, but that it sometimes dropped to as low as 0·05 inches.

Arrangements were therefore made to exercise as much control as possible to maintain the pull at a steady value of from 0·1 to 0·2 inches. This arrangement did help to a great extent, but owing to lack of flexibility it was found impossible to maintain absolutely steady conditions. For certain periods, therefore, the rich gas from the retorts was diluted by flue gas and air, and showed a low calorific value (550 B.Th.U.'s), while for other periods a balanced pull produced a gas of as high a value as 780 B.Th.U's.

A chart has been prepared showing the variation in gas yield and calorific value over the period of the test (Fig. 2). The decrease of calorific value with increased yield of gas is apparent in several instances, noticeably in the very definite peaks about 7 p.m. on Wednesday.

During the test average samples of washed gas were taken at approximately eight-hour intervals, for analysis, together with certain corresponding samples of unwashed gas.

The calorific values and analyses of the various gas samples taken are shown in the following table :—

GAS ANALYSES

——	(1)	(2)	(3)	(4)	(5)	Average of test.
Volume of gas produced per hour, cu. ft.	11,730	10,200	10,550	10,740	11,420	10,970
Period of sample, hours ..	16·0	11·0	8·5	9·0	3·5	47·0
Analysis :— (percentages) :						
CO_2 ..	3·9	4·0		4·0	3·7	4·0
C_nH_m ..	4·5	4·2		4·2	3·6	4·3
O_2	0·7	0·6	lost	1·8	1·4	1·0
CO ..	6·3	6·2		5·5	6·4	6·1
H_2	39·8	39·7		32·4	33·0	37·2
C_nH_{2n+2} ..	39·0	38·3		41·2	43·0	39·6
N_2	5·8	7·0		10·9	8·9	7·8
	100·00.					
" n "	1·20	1·26	—	1·22	1·25	1·23
Specific gravity (air = 1) ..	0·54	0·55	—	0·60	0·59	0·56
Calorific value, B.Th.U.'s per cu. ft.—						
Calculated ..	700	698	—	695	703	700
Mean from chart (Fig. 2)	702	696	722	696	730	705

Unwashed gas corresponding to above average

	Per cent.	
CO_2 =	3·7	
C_nH_m = ..	5·0	Cal. value = 765 B.Th.U's per cu. ft.
O_2 = ..	0·5	
CO = ..	5·8	Spec. gravity = 0·57 (air = 1).
H_2 = ..	36·2	
C_nH_{2n+2} =	41·7	" n " = 1·25.
N_2 = ..	7·1	
	100·0	

The general inferences to be drawn from this table are as follows :—

(1) Despite the large variations of yield and calorific value as shown in Fig. 2, the average gas compositions do not vary greatly over the periods selected.

(2) At the beginning of the test the retort temperatures were inclined to be high, particularly at the end of the setting nearest the waste gas flue. The reduction later of the high temperatures shows its effect in the decreasing percentage of hydrogen and in the increasing percentage of hydrocarbons.

(3) A normal low-temperature gas prepared at 600° C. from this coal would have shown about 16·0 per cent. hydrogen and 52·0 per cent. hydrocarbons, as against an average in this case of 37·2 per cent. hydrogen and 39·7 per cent. hydrocarbons. This difference seems to be due entirely to the higher temperature (*see* p. 17).

(4) The difference in calorific value between stripped and unstripped gas is 60 B.Th.U's per cubic foot. The thermal value of the spirit recovered amounted to approximately 74 per cent. of the heat units abstracted from the gas by stripping.

LIGHT SPIRIT RECOVERED FROM THE GAS

As already stated the crude gas was washed in two large towers with creosote oil before being measured. The wash-oil was circulated continuously through these towers in series, and a proportion drawn off continuously for fractionation. The oil containing spirit was pumped through a preheater to a steam distillation column maintained at about 100° C. The spirit and water distilled over, were separated and the crude product collected continuously. The distilled oil was used to preheat incoming wash-oil, cooled and returned to the system. In the control of the test the whole of the crude product was collected, measured and sampled, while the wash oil was sampled before and after distillation. The whole system worked very satisfactorily, but it was discovered later in the examination of the samples, that the wash-oil was being returned to the system with too high a percentage of spirit remaining in it. This would undoubtedly militate against the efficiency of the gas-scrubbing, and, therefore, reduce the possible yield of spirit. Whether this fault was due to too low a temperature or too little open steam it is not possible to say, but it would seem most likely to be the latter.

The crude product collected amounted to 176 gallons over the period of the test. This was distilled to 200° C. to free it from wash-oil, refined by washing with caustic soda and sulphuric acid and distilled (by the Engler method) to 170° C. The results of

these tests and the yields obtained per ton of coal carbonised are given below :—

Yield of crude product, 176 galls. = 1·92 galls. per ton of coal
$D_{15}^{15} = 0·812$

On removal of wash-oil this product gave 92·5 per cent. of crude spirit to 200° C. at $D_{15}^{15} = 0·809$ or 1·78 galls. per ton of coal.

On refining this crude spirit a loss amounting to 7·6 per cent. was experienced in washing and a further loss of 12·5 per cent. on distillation to 170° C., both percentages being calculated on the original product. It is quite possible that, on a large scale, these losses would not be so high.

Crude spirit ($D_{15}^{15} = 0·809$) = 1·78 gallons per ton of coal.

Washed spirit = 1·62 gallons per ton of coal.

Ref. spirit to 170° C. ($D_{15}^{15} = 0·792$) = 1·39 gallons per ton of coal.

The distillation range of the refined spirit is given below :—

40° C.	...	...	...	...	First drop.
80	...	...	...	...	2·5 per cent.
90	...	...	...	...	8·9 ,, ,,
100	...	...	...	...	24·2 ,, ,,
110	...	...	...	...	44·5 ,, ,,
120	...	...	...	...	61·0 ,, ,,
130	...	...	...	...	75·1 ,, ,,
140	...	...	...	...	86·9 ,, ,,
150	...	...	...	...	92·4 ,, ,,
160	...	...	...	...	96·0 ,, ,,
170	...	...	...	...	98·0 ,, ,,

The iodine value of the refined spirit was 41 (Wijs).

TAR

The tar and liquor were sampled together by dipping the collecting tanks at the end of the test. The total volume of the tar and liquor collected was calculated from the volume of the tanks, which were rectangular (9 feet × 6 feet). The samples were separated, the tar and liquor proportions in each calculated, and average samples of tar and liquor made up by mixing in the correct proportions.

	Tar (dry).		Liquor.	
	Galls.	Sp. gr.	Galls.	Sp. gr.
Tank 1—				
Condenser and extractor (1) ..	306	1·106	1,202	1·009
(2) ..	404	1·008	474	1·012
Tanks 2 and 3—				
Hydraulic main	995	1·100	685	1·014
Samples, seals, etc	2	—	21	—
Totals	1,707	1·063	2,382	1·010

This yield of 1,707 gallons of tar is equivalent to 18·62 gallons per ton of coal carbonised. Owing to the relatively high temperature of the retorts the specific gravity of the tar is rather high. A complete examination of the tar was not attempted, but the following are the results of investigation of a more or less preliminary character.

Calorific value (dry)	...	16,540 B.Th.U's. per lb.
Specific gravity at 15° C.		1·063
Sulphur, per cent.	...	1·20

Preliminary distillation (percentages by weight of dry tar)

——	Per cent.	D_{15}^{15}	Tar acids per cent. by volume.
To 170° C.	4·7	0·855	5·6
170 to 230° C.	14·9	0·960	38·0
230 to 270° C.	12·9	0·996	41·0
270 to 310° C.	18·1	1·041	26·0
Pitch	48·4	—	—
Loss	1·0	—	—

The total yield of tar acids amounts to 17·06 per cent. by volume of the tar or 3·18 gallons per ton of coal.

These results differ from those of a 600° C. tar made at the Fuel Research Station in that the yield of the light fraction is much less and of a higher density. The yield of tar acids is very similar.

The first fraction (0—170° C.) was examined further to determine the yield of refined spirit.

Yield of crude fraction	= 1·090 galls.	at D_{15}^{15}	= 0·855
Tar acids	= 0·061 ,,		
Loss on acid washing ...	= 0·117 ,,		
Yield after refining ...	= 0·812 ,,		
Yield after distillation to 170° C.	= 0·756 ,,	at D_{15}^{15}	= 0·828

This quantity of spirit, together with that recovered from the gas (1·78 gallons), gives a total recovery of crude spirit of 2·87 gallons or of refined spirit 2·16 gallons per ton of coal carbonised.

LIQUOR AND AMMONIUM SULPHATE

The total yield of liquor over the period of the test was 2,382 gallons or 26·00 gallons per ton of coal carbonised. It should be remembered that some of this liquor was introduced into the

system as water to cool the hydraulic mains. The water balance of the system may therefore be expressed briefly as follows :—

	galls.
Total liquor collected per ton of coal	26·00
Water to hydraulic mains	4·42
Nett liquor	21·58
Present as moisture in coal (5·2 per cent.) ...	11·65
Liquor produced per ton of dry coal	10·47

This quantity is quite normal and agrees fairly well with a figure of 11·7 gallons obtained at the Fuel Research Station.

The percentage of ammonia in the average liquor amounted to 1·33 per cent. by weight, which is equivalent to 13·55 lbs. of pure ammonium sulphate per ton of coal. This high yield is attributed only to the relatively high temperature of carbonisation.

COMPARISON OF YIELDS WITH ASSAY RESULTS

The comparison of the above yields with the results of the assay tests (page 6) are interesting. In order to obtain a true comparison the results in both cases have been calculated per ton of dry coal.

——	Yields.		Assay. On dry coal. (2)	Factor (1) : (2)
	As charged 5·2 per cent. moisture.	On dry coal. (1)		
Coke, cwts...	13·92	14·68	14·85	0·99
Gas, cu. ft...	5,620	5,930	4,105	1·44
,, therms	39·6	—	—	—
Tar, gallons	18·62	19·14	27·91	0·68
Liquor, gallons	26·00	10·47	10·07	1·04
S/ammonia, lbs.	13·55	14·29	8·70	1·64

Owing to the higher temperature of carbonisation these factors do not compare well with those already published by the Fuel Research Board.* The variations are, however, all in the right direction. The increase in the tar factor from 0·60 (as already published) to 0·68 is very interesting. The fact that the Fuel Research Station setting of horizontal retorts gave low yields of tar was recognised, the reason ascribed being the excessive amount of heating surface to which the escaping gases

* Report of the Fuel Research Board for the years 1920–21. Second Section : Low Temperature Carbonisation (p. 33). Published by H.M. Stationery Office. Price 2s. net.

are subjected. It was only to be expected, therefore, that in a vertical retort of the Parker type a higher efficiency of tar-making would be attained. It would seem possible also that, with a better control of temperature to a mean of not more than 650° C., an even higher efficiency could be attained.

GENERAL OBSERVATIONS ON THE CAPACITY AND HANDLING OF THE PLANT

Throughput of Coal

As already stated the setting under examination contained thirty-two retorts operated in pairs. The nominal throughput for such a setting was stated to be 50 tons of coal per 24 hours.

Owing to the breaking of the bottom door of a retort two retorts were not in operation at all. The remaining thirty retorts were worked continuously except for one or two short intervals when trouble was experienced with choked gas-outlet valves.

The total weight of coal carbonised in forty-seven hours amounted to 91·66 tons and the throughput may be expressed as follows :—

——	30 retorts as worked.	Calculated to 32 retorts setting.
Coal carbonised per 24 hours, tons	46·8	50·0
„ „ „ hour, tons	1·95	2·08
„ „ „ retort per day, tons ..	1·56	1·56
Number of double charges	167	—
Weight of coal per charge, cwts.	10·98	10·98

From the above it is evident that the equivalent of the throughput of 50 tons per day of coal, for which the retorts were designed, has been realised. The figure of 10·98 cwts. per charge refers of course to two retorts.

The time of carbonisation varied somewhat throughout the test. For the first 15 hours it was maintained steadily at just over four hours, only one retort giving trouble and required an extended period to five hours. After this, the time of carbonisation was reduced for a few hours to 3·7 hours, but later the full period of 4·0 hours was again resorted to, some charges even having as long as 5·0 hours again. Occasionally an attempt would be made to discharge a retort only to find that the coke could not be poked out. An additional half-hour or so was generally sufficient to relieve this. After about 20 hours working trouble was experienced with certain of the gas-outlet valves

sticking and the retorts affected were forced to lose a certain amount of time. The time lost over the period of the test amounted to approximately three full charges. The average time of the various operations are detailed below :—

Time of carbonisation (mean)	4·10 hours.
Time of operation (discharging and charging) (mean)	8 mins.

The actual time of operation of one retort is therefore 4·23 hours, of which time 8 mins. or 0·13 hour is consumed in the necessary operations.

The coke production will necessarily vary with the type of coal being carbonised. In this instance it amounted to 38 tons per day, assuming the full setting in working order.

Temperature of Carbonisation

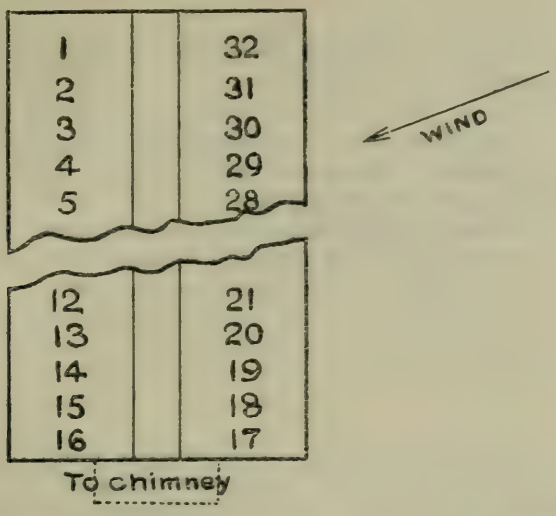
Owing to lack of protection from the atmosphere the setting was subjected to fairly wide variations of temperature.

Each retort was heated from two combustion chambers separated from it by a perforated brick wall. The fuel gas, a mixture of coal gas with producer gas, was burned in these chambers and the hot gases passed through to the retorts, the air for combustion being supplied through open ports in the side of the chambers. The flue passed down the centre between the two rows of retorts and dampers were arranged to equalise, as far as possible, the draught from each chamber. This arrangement was, however, far from successful and in general it was evident that the retorts nearest the chimney were much hotter than those at the extreme end. Certain of the combustion chambers were also adversely affected by the wind and were difficult to control. A better system would have been to close the combustion chambers to the atmosphere and to supply the necessary air under pressure.

The average temperatures of the combustion chambers varied from 800 to 1,000° C., while those of the retorts themselves were found to be as follows :—

First half of test—		
Retorts	1 to 5 ...	550 to 600° C.
,,	6 to 10 ...	600 to 650° C.
,,	10 to 14 ...	650 to 750° C.
,,	15 to 18 ...	750 to 850° C.
,,	19 to 32 ...	620 to 650° C.
Second half of test—		
Retort	1 ...	550° C.
Retorts	2 to 4 ...	600 to 650° C.
,,	5 to 10 ...	640 to 700° C.
,,	11 to 20 ...	660 to 720° C.
,,	21 to 22 ...	Off.
,,	23 to 32 ...	650 to 700° C.

The plan shown below gives an idea of the arrangement and numbering of the retorts relative to the position of the chimney and the direction of the wind :—



There seems no doubt that the temperatures as a whole were in excess of the intended average of 650° C. The causes of this variation are, partly, as expressed above, the situation of the setting and the design of the combustion chambers and partly the nature of the fuel gas. This gas was an imperfect mixture of rich coal gas and producer gas and layering must have occurred from time to time in the holder supplying the burners.

Fuel Gas to Setting

The fuel gas to the setting was a mixture of all the coal gas made, together with an added quantity of producer gas. During the test the total amount consumed was as follows :—

	Cu. ft.	Therms.
Coal gas at 705 B.Th.U's. ...	515,650	3,635
Producer gas at 104 B.Th.U's. ...	275,670	287
Total	791,320	3,922

This total amounted to 16,840 cubic feet or 83·5 therms per hour to the setting. In normal practice the amount could be greatly decreased and a uniform temperature of 650° C. maintained if better heat insulation were incorporated in the design. The addition of heat insulating bricks to the setting would also make a considerable difference, particularly on the top of the setting, where the iron plates were always uncomfortably hot to stand on. Even with the present arrangement the additional 7·3 per cent. of heat value in the producer gas seems quite unnecessary, and this gas is apparently useful only as a diluent.

The composition of the producer gas was approximately CO_2, etc., 13·6; C_nH_m, 0·5; O_2, 0·2; CO, 10·4; H_2, 8·6; CH_4, 3·5; and N_2, 63·2.

Labour, Power, etc.

The labour provided for the handling of the 50-ton unit in operation was as follows:—

	Men.
Handling of coal and coal trucks, etc. ...	3 (day-shift).
Running exhauster, tar extractor and spirit recovery plant	1 (8 hour-shift).
Running gas producer and coal elevator	1 ,,
Charging and discharging retorts ...	3 ,,
Discharging coke chambers and removing coke	4 ,,
Foreman	1 (day-shift).
Total	13

The above labour is undoubtedly more than enough for one such unit and could be greatly reduced by the application of mechanical devices. One arrangement which could be considerably improved is that of the bottom doors of the retorts. These doors are opened and closed by a handwheel in a manner which is both laborious and wasteful of time.

The power consumed could not be measured under the conditions of the test, but the maximum capacities of the motors driving the plant were as follows:—

	H.P.	
Coal elevator 1	7	8 hours for 100 tons.
,, ,, 2	3	8 ,, ,,
Moving of coal and coke petrol tractor	18	As required.
Tar pumps	(Steam)	9 hours for product from 100 tons of coal.
Spirit recovery pumps ...	3	Operated continuously.
Gas exhauster	(Steam)	,, ,,
Spirit recovery (distillation)	(Steam)	Continuous supply.

SUMMARY

A CARBONISING test is described as carried out by the staff of the Fuel Research Station on an installation of "Parker" low-temperature retorts installed at the works of the Low Temperature Carbonisation Company, at Barnsley.

The plant available consisted of two units each capable of carbonising 50 tons of coal per 24 hours. The test was carried out on one of these units after it had been in continuous operation for a period of some eight days on Dalton Main coal.

Observation of the working of the retort for a period of 48 hours showed that steady conditions had been attained, and a

test was then started in which it was intended that over 100 tons of coal should be carbonised. This test had to be discontinued owing to a breakdown of the exhauster plant. On re-starting, shortage of coal necessitated the restriction of the test to 92 tons of coal.

The coal used was Dalton Main (Rotherham), a coal with which the Fuel Research Station have had considerable experience. The analysis of this coal and its properties when examined in the laboratory assay apparatus are described.

The setting used for the test is described. It consists of a battery of 32 retorts heated by a mixture of coal gas and producer gas. The retorts are of cast iron, each consisting of a nest of twelve 5-inch tubes. Below each pair of retorts is a cooling chamber for coke.

During the test samples were taken of the coal and of the products of carbonisation. The conditions of working and the labour required were carefully noted. The samples collected were all reduced as far as possible and brought to the Fuel Research Station for examination.

In order to determine whether the test had been a satisfactory one a weight balance was prepared and found to show a loss of 0·48 per cent. This, in conjunction with the thermal balance loss of 5·2 per cent., may be regarded as very satisfactory.

The yields of products per ton of coal were as follows :—

Coke	13·92 cwts.
Gas	5,620 cu. ft. or 39·6 therms.
Tar	18·62 gallons.
Liquor	26·00 ,,
Crude spirit	1·78 ,,
Ammonium sulphate	13·55 lbs.

The coke or smokeless fuel produced was of a very suitable size (1 to 3 inch pieces). It was not friable, and contained only 4·6 per cent. of breeze. Analysis of this coke showed that it contained rather a low percentage of volatile matter (approximately 4 per cent.). When burnt in a household grate it was readily ignited and gave a good hot fire. This fire showed less flame than the coke cakes as manufactured at the Fuel Research Station, as was to be expected from its low content of volatile matter.

The yield of tar was high, representing 68 per cent. of that obtained in the assay apparatus. On examination this tar proved to be a normal low temperature tar.

The yield of gas was fairly high and, throughout the test, varied considerably both in volume and in calorific value owing to variations of pressure in the hydraulic main.

The yield of ammonia is also fairly high. The liquor is, however, less than 6 oz. strength, and it is questionable whether so dilute a liquor would justify recovery.

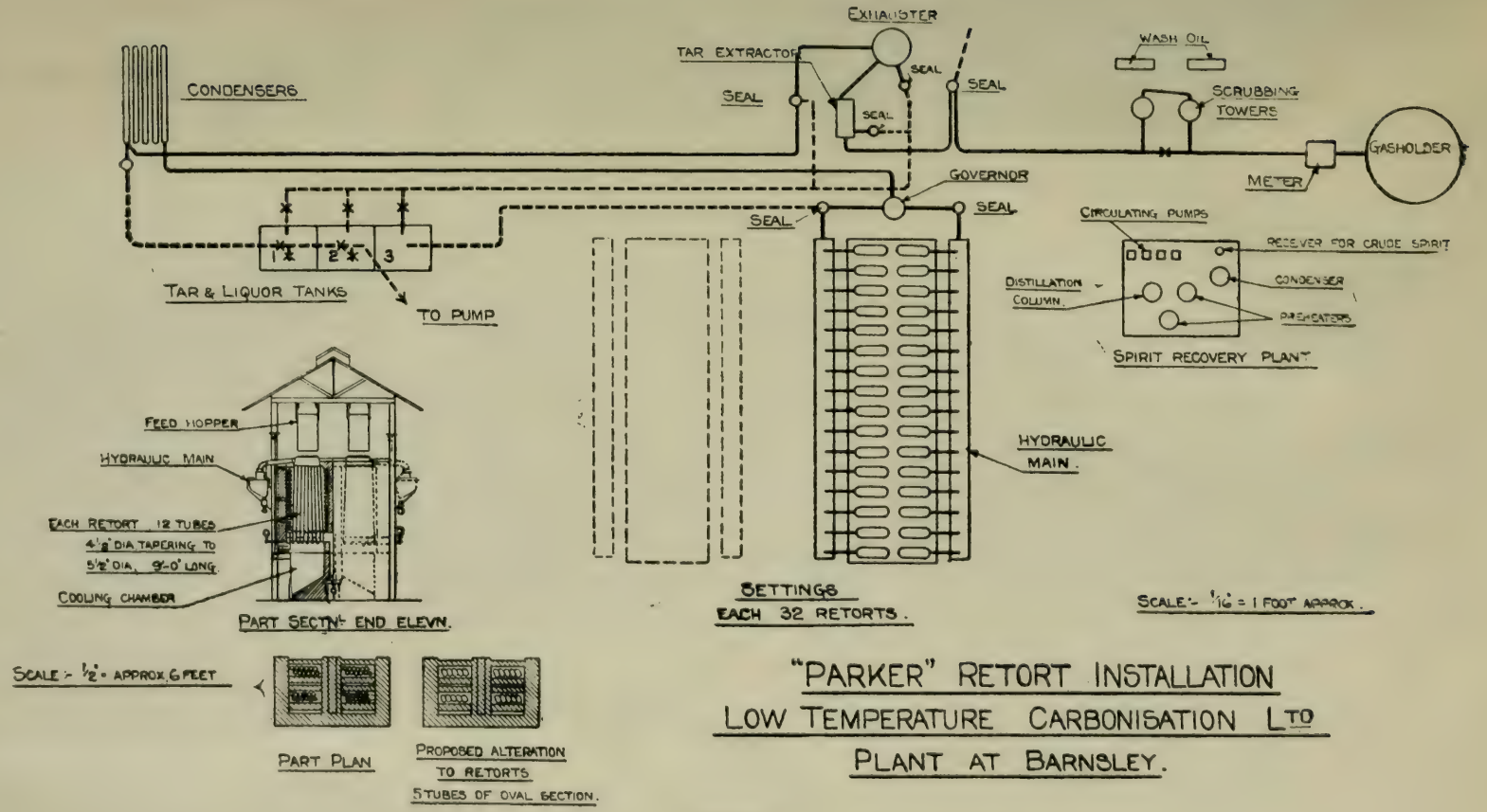
The spirit obtained by scrubbing the coal gas amounted to 1·78 gallons per ton of coal. The refining figures and distillation range of this spirit are given in the report.

Details are given of the working operations, of the labour and power required, and of a variety of noticeable points in the handling of the setting.

The temperature of carbonisation was not uniform throughout the setting, varying from 600° C. to as high as 800° C. Suggestions are given for the improvement of temperature control. The amount of fuel consumed on the setting was excessively high owing to this high temperature, to insufficient heat insulation and to badly designed combustion chambers. There is no doubt but that the 83·5 therms consumed per hour could be reduced considerably.

(*Signed*) C. H. LANDER,
Director of Fuel Research.

25th August, 1924.



"PARKER" RETORT INSTALLATION
LOW TEMPERATURE CARBONISATION LTD
PLANT AT BARNSLEY.

FIGURE 1.

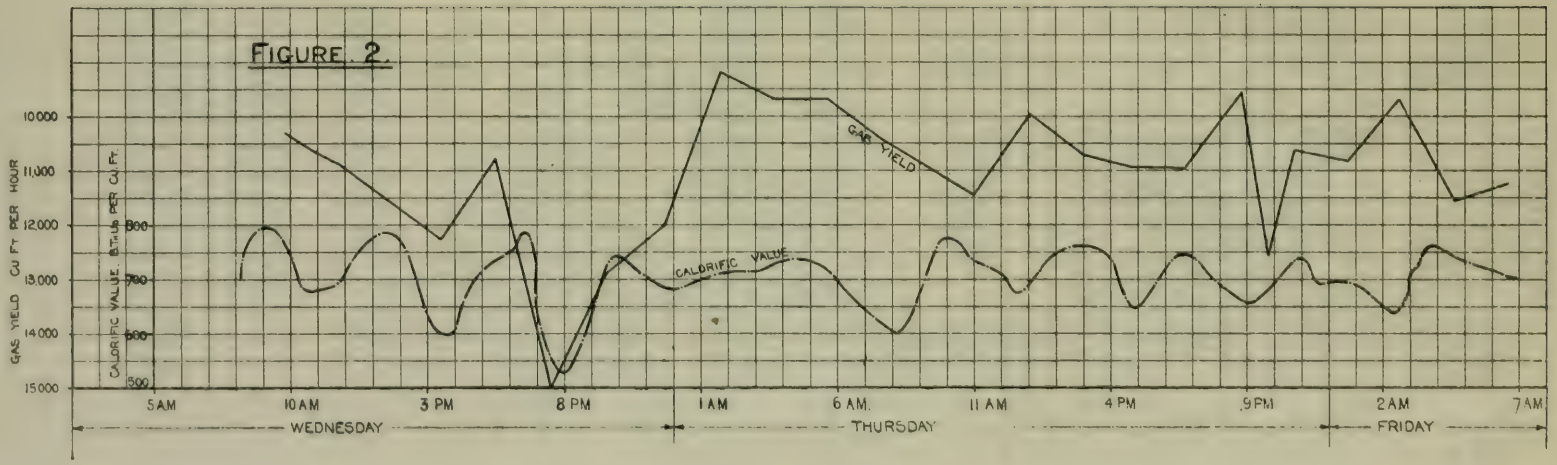


FIGURE 2.
GAS YIELD CU FT PER HOUR
10,000
11,000
12,000
13,000
14,000
15,000
CALORIFIC VALUE B.T.U.s PER CU FT.
800
700
600
500
GAS YIELD
CALORIFIC VALUE
5 AM
10 AM
3 PM
8 PM
1 AM
6 A.M.
11 AM
4 PM
9 PM
2 AM
7 AM
WEDNESDAY
THURSDAY
FRIDAY

APPENDIX

CONDITIONS UNDER WHICH THE DEPARTMENT IS PREPARED TO TEST PLANTS FOR LOW TEMPERATURE CARBONISATION OF COAL

The Department of Scientific and Industrial Research, Old Queen Street, S.W.1, is prepared to undertake in approved cases tests on plants for low temperature carbonisation. The objects of the test are to ascertain the quality and quantity of the yields of coke, tar oil, gas and ammonia, the throughput of the plant, working temperatures, and general ease and reliability of working. No charge will be made by the Department in respect of the tests, but applicants will be required to comply with certain conditions and to sign an Agreement embodying the terms on which this offer is made. Forms of application may be obtained from the Secretary, Department of Scientific and Industrial Research, 16, Old Queen Street, Westminster, S.W.1. The nature of these conditions can be ascertained from the following particulars, but the Department reserves the right to add to or alter them as may be thought necessary.

(1) Applicants will be required, before the Department can undertake a test, to supply full information as to the nature of the plant and results obtained and to afford facilities for the inspection of the plant by one or more officers of the Department, and generally to satisfy the Director of Fuel Research that the plant is giving reasonably good results and is of such a size that its performance will be comparable with that of a similar plant operating on a commercial scale.

(2) Tests will be under the continuous supervision of such members of the Fuel Research staff of the Department as the Department may decide, who may take as samples such amount as they may consider necessary both of the coal used and of the products.

(3) Applicants must at their own expense provide all necessary facilities, including all material staff and labour required for running the plant, and for such assistance in taking samples and measurements as may be required by the Department or its officers supervising the test.

(4) Until the information referred to in paragraph (1) above has been supplied and a preliminary inspection of the plant has been made it is impossible to state what facilities will be required or to give any indication of the programme or possible duration of the test, which may vary from several days to several weeks according to circumstances.

The necessary facilities will in any event include proper arrangements for taking such measurements as will give a satisfactory weight balance between the input and output of the plant.

(5) Applicants will be permitted to have a representative present during the test who will be allowed to check any weights or measurements forming an integral part of the test.

(6) The decision of the supervising officer of the Department in charge of the test will be final in regard to all questions relating to the duration and conduct of the test and all weights, measurements and other matters in connection therewith.

(7) The Department reserves the right to publish a report on the test at any time at its discretion, but will before so doing consult the applicants, and any views the latter may express will receive consideration. A copy of the report will, at the request of the applicants, be furnished to them free of charge. Applicants will not be entitled to publish or communicate to third parties such report or any extract from or allusion to it without the consent in writing of the Department. Such consent may be conditional.

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10 24 (B.34-2267)T 1421—104 500 1/25 H & S Ltd. Gp. 34 (1837)